Spatial Variation of Wind Stress and Wave Field in the Shoaling Zone

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LONG-TERM GOALS

Existing atmospheric models for predicting surface stress and turbulent structure in the shoaling zone fail because of their inability to properly account for wave age, shoaling, and internal boundary layer development. Accurate model simulation of the surface stress and turbulence above the air-sea interface is important for a number of applications including understanding wave growth and decay. Under this ONR Advance Research Initiative, our goals are:

1. to measure the spatial variation of the wind, surface stress and ocean wave fields in the shoaling zone and to provide quality-controlled data to the shoaling community; and

2. to study the relationship between the spatial varying mean wind, stress, turbulence structures, and surface wave fields in order to model effects of wave age, shoaling, and internal boundary layer development on the drag coefficient and momentum transfer.

OBJECTIVES

The key to achieving our goals is the development of a data archive containing simultaneous observations of the spatially varying wave, wind, and stress fields in the shoaling zone. At the start of this project, instrument systems for making such observations did not exist. This year, we completed our first objective which was to develop and demonstrate an efficient measurement system. This report focuses on instrument system development and its application in a pilot study.

APPROACH

The LongEZ (N3R) research aircraft (http://www.noaa.inel.gov/frd/Capabilities/LongEZ/) is well known for its high fidelity observations of mean meteorological parameters and mass, momentum, and energy flux in marine boundary layers (Fig. 1). However, missing was the ability to measure wave

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height, roughness, phase speed, and directional spectra. To supplement these measurements, a pod was added below the aircraft containing a Ka-band radar and laser altimeter array. These new sensors were integrated into the data system and processing software. With such a novel airborne system, we could, for the first time, freely explore the spatially developing wind field, surface stress, and wave field within the shoaling zone.

Figure 1. LongEZ N3R at 10 m above the sea surface during the SHOWEX pilot study.

WORK COMPLETED

In preparation for the spring pilot study, all instruments were calibrated and installed on N3R. During March 1999, 23 missions covering 75 flight hours were flown under various atmospheric and wave field conditions at the U. S. Army Field Research Facility (FRF) located in Duck, North Carolina. Post field study calibrations were completed and applied to data acquired. Flight scenarios included parallel and perpendicular runs at various altitudes with respect to the coastline as well as numerous slant and spiral soundings. N3R also acquired meteorological information on the boundary layer structures over the nearby Albermarle and Currituck Sounds. Several flights were flown over Lake Mattamuskeet in an attempt to further understand internal boundary layer development. All data were made available to collaborating scientists in netCDF format on CD-ROM.

During September and October, final preparations were completed to N3R for the participation in the Shoaling Wave Experiment (SHOWEX) experiment. Major work focused on flight tests to insure instrumentation and the data system were functioning correctly. Flight maneuvers included pitch and yaw calibrations. Wind circles and boxes were included to verify the proper measurement of the wind. Low-level legs were also included over Mud Lake near Terreton, Idaho to verify the proper operation of the laser altimeter array and the Ka-band radar (scatterometer). In addition, the data acquisition and post-processing software that are to be used for these experiments were updated to provide a more robust system than in previous field campaigns.

We are also cooperating with Dr. Ken Melville of the Scripps Institute of Oceanography (SIO) to develop a new Wave Breaking and Dissipation measurement system for the November SHOWEX field study. The Modular Aerial Sensing System (MASS) will measure the kinematics and dynamics of breaking waves in the transition zone between deepwater breaking and depth-limited breaking on the continental shelf. MASS will allow the geometry, kinematics, and statistics of breaking leading to whitecaps to be measured using video imagery from the LongEZ. Image sequence analysis will be used to determine L(c)dc, the length per unit area of breaking crests in the velocity range (c, c+dc). SIO will correlate this fundamental statistical distribution function and its moments with bottom topography and with wind and wave variables, including the wave directional spectrum. The prototype MASS prototype was initially tested on N3R in November 1997. More information can be found at http://www-mpl.ucsd.edu/people/melville/MASS.htm/. Figure 2 shows the instrumentation to be flown during the November 1999 SHOWEX field study. Not shown is the MASS system. The MASS computer system will mount above NOAA s main computer system. The MASS video cameras mount in the tail section of the pod just behind the NASA Ka-band radar.

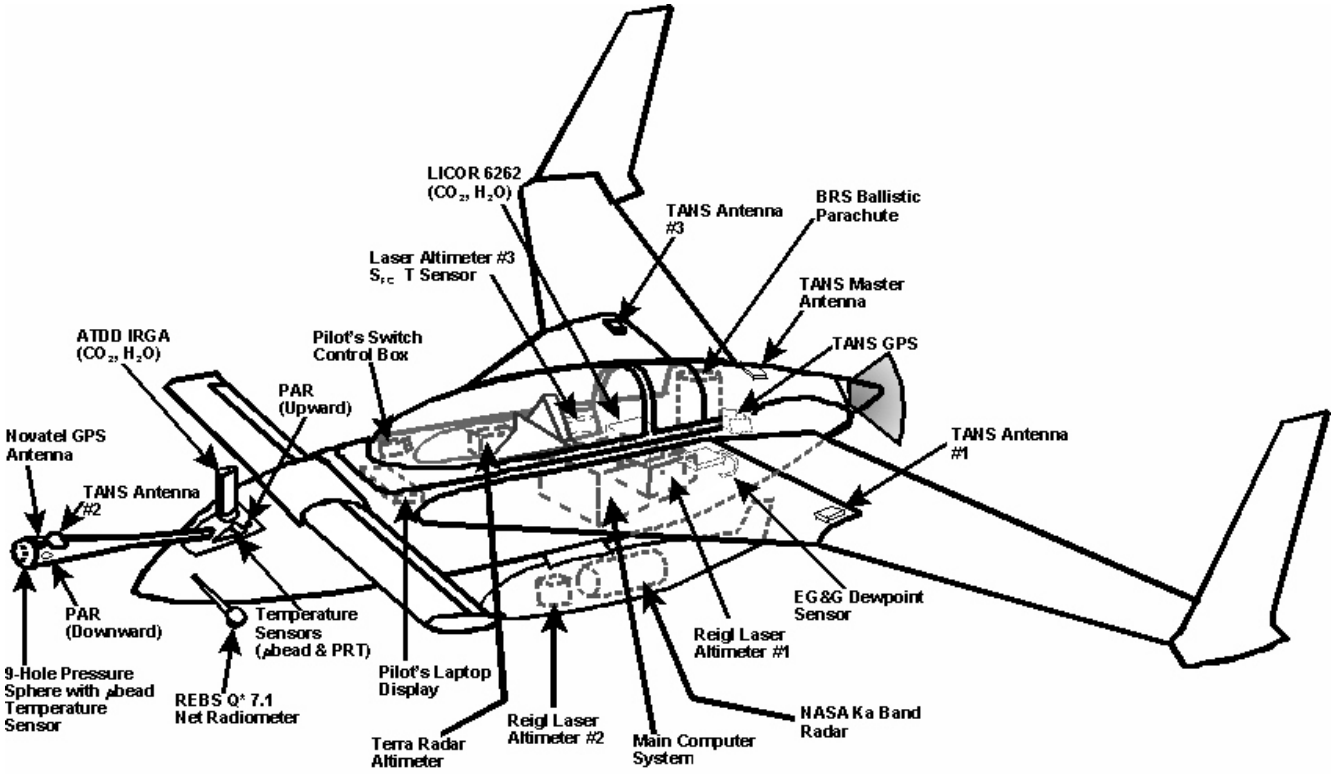

Figure 2. Identification and location of the various instrument systems on LongEZ N3R.

RESULTS

The SHOWEX spring pilot study was successfully conducted at the U. S. Army Corps of Engineers Field Research Facility (FRF) located in Duck, North Carolina during a three-week period in March 1999. N3R flew 23 missions (75 flight hours) under a variety of atmospheric and wave field conditions. High fidelity turbulence flux measurements have been acquired by N3R during the SHOWEX spring pilot study. These measurements included the mean and turbulent wind field, heat flux, and moisture flux. The Ka-band radar, designed by Doug Vandemark of NASA, has demonstrated the ability to measure the mean square slope of ocean waves with a footprint one meter

in size. The array of three laser altimeters has been used to observe the characteristics of the larger waves. The data from this pilot study was quality controlled and is available as netCDF files via CD-ROM or FTP. Collaborating scientists are currently analyzing these data. Publications are listed below.

IMPACT/APPLICATIONS

Our laser array approach has proved successful and is being adapted by others. Dr. Mark Donelan has adopted the laser approach for wave measurement from a ship. NASA, recognizing the power of the airborne laser wave measurements, funded the Wave Profile Experiment (WAPEX) to reduce the uncertainty in the electromagnetic range bias that corrupts satellite sea surface topography measurements (http://www.noaa.inel.gov/frd/Projects/wapex.html/). N3R laser measurements are being used to refine EM bias models for large-scale tilt, short-scale diffraction, and hydrodynamic effects.

TRANSITIONS

The pilot study data archive is being analyzed in detail by Jielun Sun and Larry Mahrt. We are also advising Mark Donelan on the development of wave measurement system for shipboard use.

RELATED PROJECTS

Although funded separately, this project is a cooperative effort with Doug Vandemark (NASA, Ka-band radar development and analysis, N00014-97-F-0179), Jielun Sun (NCAR, data interpretation, N00014-98-1-0245), and Larry Mahrt (Oregon State University, data interpretation, N00014-97-1-0279).

PUBLICATIONS

Crescenti, G. H., T. L. Crawford, and E. J. Dumas, 1999: Data report: LongEZ (N3R) participation in the 1999 Shoaling Waves Experiment (SHOWEX) spring pilot study. NOAA Tech. Memo., ERL ARL-232, Silver Spring, MD, 86 pp.

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